Investigation of Poisonous Gases using Micro Ring Resonator for Sensing Application

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Abstract: Detection of gases becomes mandatory for the safety, as leakage of the gases are harmful for environment. While, this work reports the monitoring of three poisonous gases with structure of micro-ring resonator. The variation of different radii from 1.4 µm to 2.2 µm, by changing the radii of inner resonator is analyzed with refractive index of analytes. The poisonous gases, like, hydrogen (H_2), nitrogen (N), and Sulphur dioxide (SO_2) are detecting at the initial stage of leakage. The results of transmission are examined at low concentration and show the sensitivity of three poisonous gases.

Keywords: Micro ring resonator, refractive index, fiber optic sensor

1. Introduction:

Optical fiber technology is used predominantly for sensors designing [1,2]. The fiber optics has the main advantage for use in the industry due to its superior properties and it also has characteristics over light transmission and data transmission. Their main features are high sensitivity, selectivity, small size, fast response, and capability of sensing application. Hence, researchers are focusing on FOSs sensor due to its features,which can be used in many applications like farming, biomedical, chemical industry and household work. There are diversedevices for sensingharmful gases, such as micro-Optical sensors [3], surface plasmon [4,5], fiber Bragg grating [6,7,8,9] and ring resonator [10,11]. For the safety of people, sensing gas analytes are important, because if these gases will leak at higher concentration, then it became difficult to take breathe or sometime deadly act. That's why it's very important to detect the leakage of poisonous gases. Gases are very important chemicals for uses in the environment. Sometimes they are very useful and sometimes gases become cruel for the environment [12,13,14]. Nowadays everyone is using different poisonous gases in their daily life. That's why the detection of gases becomes a key topic for everyone. Gas sensors work as detection methods, which produce an alarm to alert the people about the leakage of gas at high concentration. If the gas sensor worked on early detection, then an alarm ring at an early stage for the leakage of poisonous gases at an accurate time or correct measurement. The benefit of this type of early detection is that the people are working get out of the working place or switch off the leakage cylinder. The parameters used for the detection

of gases are including sensitivity, selectivity, detection limit, response time, and recovery time. The author proposed the structure of surface plasmon resonance for utilizing the ZnO nanoparticle for the detection of H_2S [5]. They have discussed the result of wavelength and the concentration of hydrogen sulfide gas. This sensor is useful in many applications like food, medical, and the textile and the environment sciences. To achieve a higher sensitivity the structure of ring resonator coated with metallic nanoparticle is used to detect biomedical sensor [15]. They demonstrate the structure Mach–Zehnder interferometer coated with copper/graphene oxide (Cu/GO) in multi-point thin-core fiber. The sensitivity of 4.83 pm/ ppm is attained [16].
This work proposed the structure of the Micro Ring Resonator (MRR) for the detection of three poisonous gases.The three gases are hydrogen (H_2), nitrogen (N), and Sulphur dioxide (SO_2) and these are dangerous in the environment with a wide range of exposure. The proposed sensor is designed in OptiFDTD software by changeable the RI of the outer ring waveguide.The transmission of MRR is perceived and sensed the different poisonous gases.

These are the toxic gases that are used in everyday use such as industry, house, agriculture, and environment. Some of them are made by natural and some of them are made by man. The exposure of these gases is very imperious for the well-being of the atmosphere. If the leakage of these gases is high it will cause some serious health problem or sometimes it also causes death. The H_2 is a colorless, odorless, tasteless gas created by burning gasoline, wood, propane, charcoal, or other fuel. It is sometimes called carbonic oxide or silent killer. It becomes a liquid under high pressure. Similarly, N is also colorless, odorless, and highly flammable. SO_2Called laughing gas as well, which used for people to get intoxicated. It is a colorless non-flammable gas at room temperature. It is also used as an oxidizer in rocket propellants, and in motor racing to increase the power output of engines.

2. Working Principle of the proposed sensor

The proposed sensor is simulated by using FDTD. The function of the sensor is used as micro sensors and used for detecting poisonous gases, such as H_2 , N , and SO_2. The input Optical signal passes through the Optical linear waveguide and coupled the signal to ring waveguide. The light coupled to the ring waveguide through the coupling coefficient. As the distance between linear waveguide and ring waveguide is less, the coupling coefficient is easy and has less loss. Meanwhile, the coupling is variable by the distance between linear waveguide and ring waveguide, and its illustration that if the distance is closer coupling is easy. The sensor worked as the refractive index of the outer ring is changed and analyzed that sensor is worked for all three gases. Figure. 1.Illustrations schematic of the proposed sensor of the ring resonator, where r_1 are the radius of the outer ring and r_2 the radius of the inner ring which coupled with the linear waveguide. The coupling length C_L, which can vary by variation of radii of the outer and inner ring. The length of the linear waveguide (L = $8\mu m$) and width (W = $0.5\,\mu m$), where the distance between linear waveguide and ring waveguide depends on coupling distance.The inner part of the ring waveguide is worked as a sensor and the outer part of the ring waveguide is worked as a sensing application by changing the refractive index of three poisonous gases. Three gases, hydrogen, nitrogen, and Sulphur dioxide are kept by changing the refractive index, where an evanescent wave of outer ring interact and

senses the poisonous gases. The Lorentz Drude model is used for calculating the refractive index of three poisonous gases [17]. In this paper, the refractive index hydrogen (H_2) is 1.000132, nitrogen(N) is 1.000298 and Sulphur dioxide (SO_2) is 1.000686 considered for analysis.

3. Simulation Result and Discussion

The results of the proposed sensors are analyzed in the Opti FDTD analyzer software. The different three gases are analyzed by changing their refractive index of inner ring waveguide. Three gases are carbon monoxide, phosphine, and nitrogen dioxide are used for sensing by the micro-ring resonator. The variation of the radius of the ring is supported obtainable and transmission concerning wavelength is observed. In Fig. 2. Demonstrations the transmission curve for hydrogen gas at different radii of the ring resonator, where r_1= 1.4µm, 1.6µm, 1.8µm, 2.0µm, 2.4µm, 2.4µm.

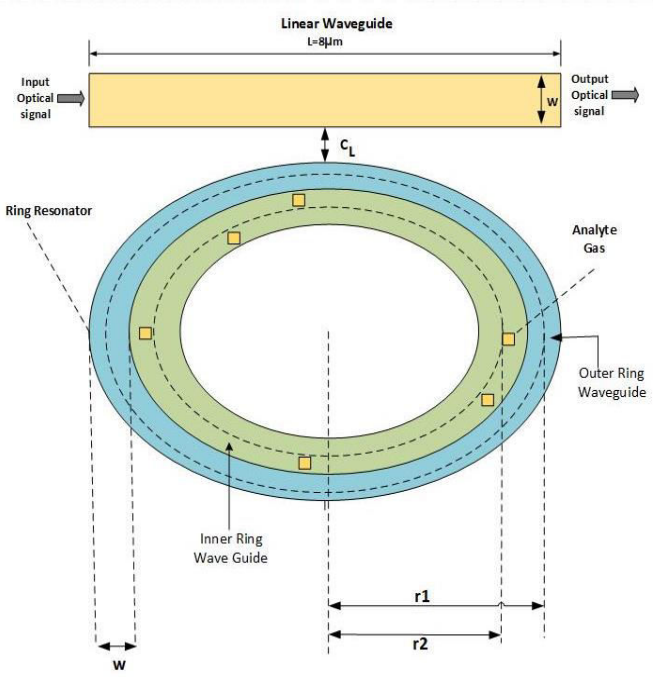

Fig. 1: Proposed ring resonator sensor

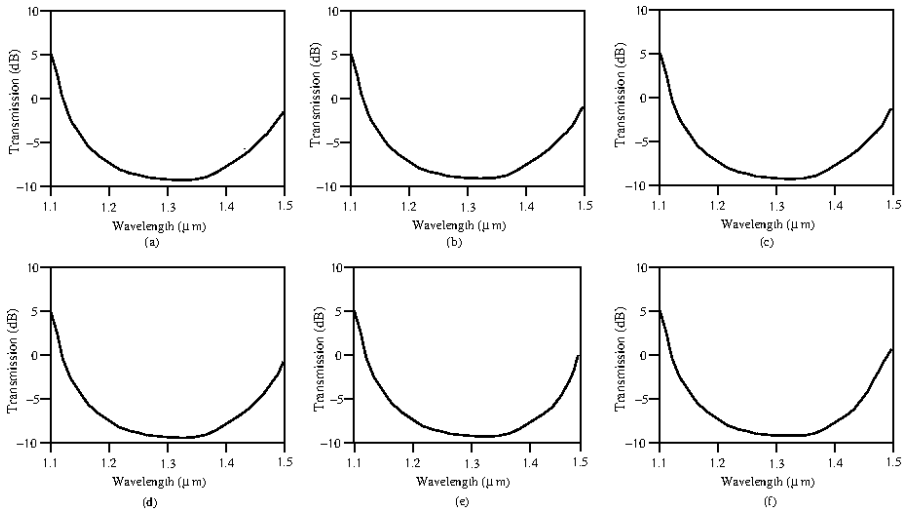

Fig. 2.: Transmission curve for H_2 gas at different outer radii(r_1), (a)= 1.4µm, (b) = 1.6µm, (c) = 1.8µm, (d) = 2.0µm, €= 2.2 µm, (f) =2.4µm

Figure.3. illustrations the transmission curve for nitrogen gas at different radii of the ring resonator, where (r_1)= 1.4µm, 1.6µm, 1.8µm, 2.0µm, 2.2µm, 2.4µm. Whereas the transmission vs wavelength curve for nitrogen dioxide gas with different radii of the ring resonator is shown in Fig 4, where (r_1)= 1.4µm, 1.6µm, 1.8µm, 2.0µm, 2.2µm, 2.4µm.

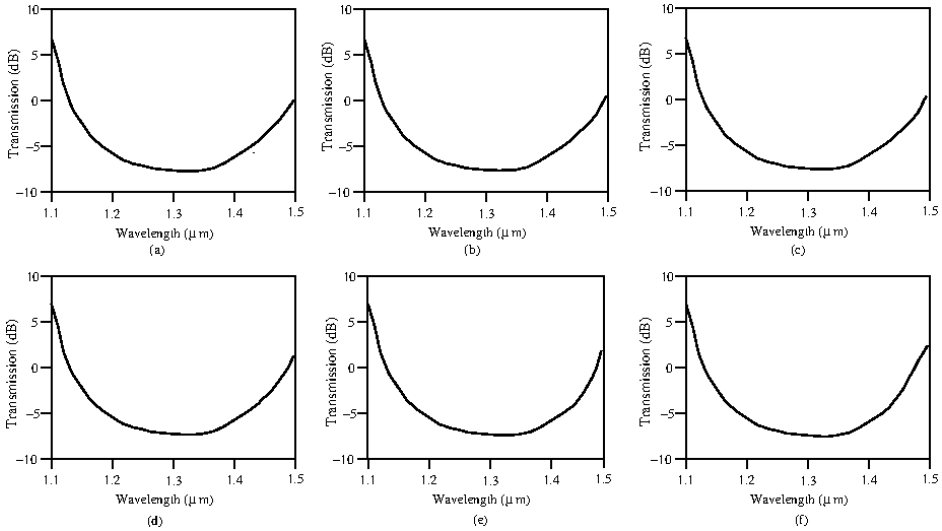

Fig. 3: Transmission curve for nitrogen gas at different outer radii (r_1) (a) = 1.4µm, (b) = 1.6µm, (c) = 1.8µm, (d) = 2.0µm, € = 2.2 µm, (f) =2.4µm

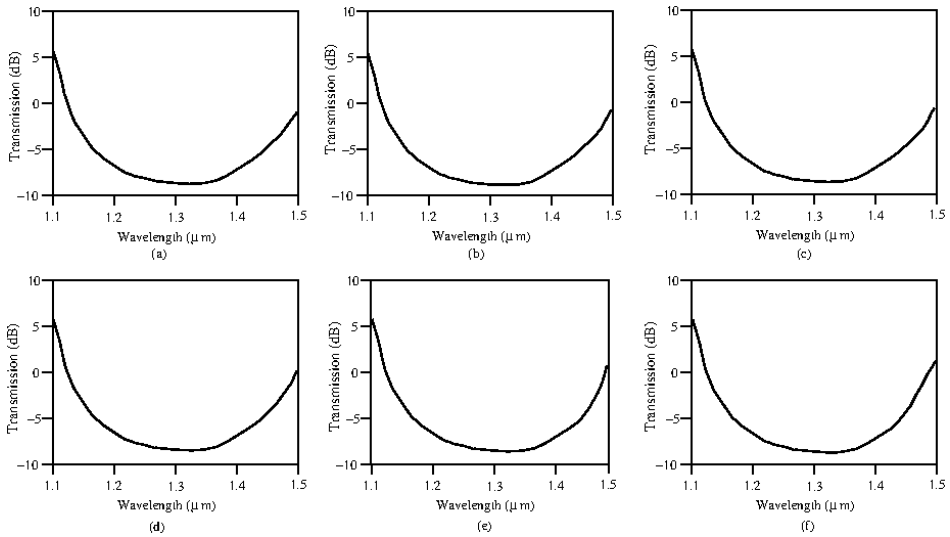

Fig. 4: Transmission curve for Sulphur dioxide gas at different outer radii (r_1) (a) = 1.4µm, (b) = 1.6µm, (c) = 1.8µm, (d) = 2.0µm, € = 2.2 µm, (f) =2.4µm

Whereas, combine results of all three gases such as hydrogen (H_2), nitrogen $(N$ $)$, and Sulphur dioxide (SO_2) are shown in Fig. 5, which shows the transmission vs wavelength curve. It seems from the figure that different gasses have different transmission curve. It is due to the variation in the refractive index of gases.

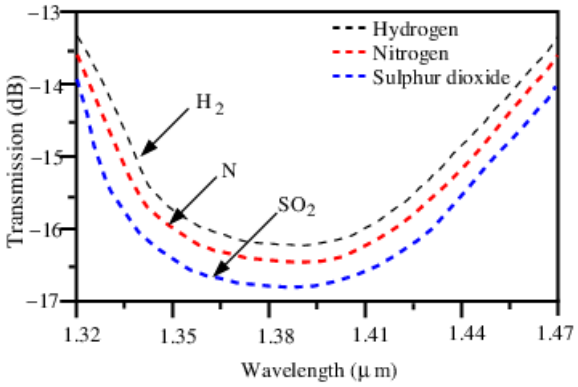

Fig. 5: Transmission curve vs wavelength for H_2 , N , and SO_2 at radius1. 4µm

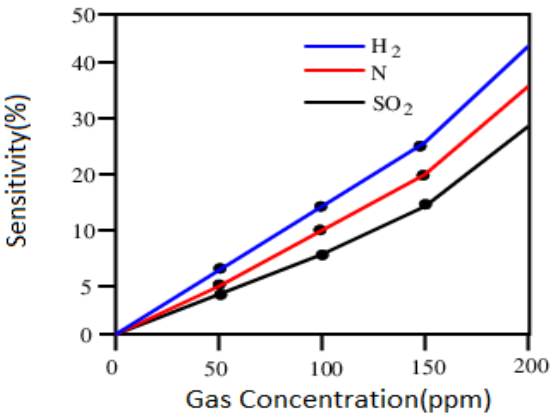

Fig. 6: Sensitivity Vs concentration for H_2 , N , and SO_2 at radius 1. 4µm

Simultaneously, the sensitivity of three poisonous gases shown in Fig 6, which curve show the curve of sensitivity Vs concentration. The concentration range is in between 0ppm to 100ppmand observed that that hydrogenshows the good sensitivity response at initial stage.

4. Conclusion

In conclusion, sensor based on micro ring resonator for detecting the different poisonous gases, such as hydrogen (H_2), nitrogen (N), and Sulphur dioxide (SO_2). The three gases are analyzed by a ring resonator device in Opti FDTD software. The transmission vs wavelength curve is plotted with a center wavelength of 1550nm, where combined results of three poisonous gases are observed by varying radii of 1.4µm, 1.8µm, and 2.2µm, which shows that radius with 1.4µm has low loss, means loss is decreasing with size of the micro-ring resonator. It also shows that as the coupling coefficient distance between the linear waveguide and ring waveguide is less, a loss is also less. Thereafter, three gases are analyzed at radius 1.4µm. It is clear from the results that different gases can be detected by the proposed sensor. The advantage of these sensors is used for the safety of next-generation as the gas exposure and detect at the leakage of a low level. Whereas these sensors helped us to get rid of the harsh environment in industries or doing household works.

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